Improving the use of Science in Environmental Assessments

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ABSTRACT

Scrutiny of Environmental Impact Statements (EIS) as scientific documents is still in its infancy in Australia, yet we already have litany of complaints about their quality. My examination of 131 EISs covering a range of projects, habitats and legislatures revealed that few tackled ecological issues and mostly without a quantitative approach utilizing statistical analyses. I therefore conclude that the science in EISs is rather more rudimentary than the standard seen in ecological journals. Here I outline the genesis of problems with how science is used in environmental assessment and suggest several means by which scientists and regulatory authorities can try to rectify the situation. These suggestions revolve around my central point that the image of Environmental Impact Assessment (EIA) needs to be put more positively — to deserve this requires, in turn, a higher standard of scientific input and use. Even if some environmental impact studies verge upon being pseudoscientific, they should be of interest still to the wider scientific community precisely because they are an important interface between scientific research and public interests. Without optimising this public face of science we run the risk of alienating the ultimate source of support for our science.

INTRODUCTION

Both the scientific community and the public have voiced concerns about the role that science now plays in environmental protection (see e.g., Constable 1991; Peterson 1993). This paper attempts to be prescriptive in that I set out how environmental impact assessment, monitoring and auditing *should* be done. Only be setting out such ideals can we know what to strive for! The subject will be dealt with from a technical viewpoint rather than a focus on procedures. So here is my opinion, offered in a positive vein, hoping to transcend present limitations on environmental management. It is a meld of viewpoints reflecting my concern over the needs of research, especially in ecology, the obligation for statistical rigour in good science and the influence of environmental philosophy (Fairweather 1993).

What is EIA?

Environmental impact assessment has particular aims. This is because it is a process of decision making that has legislative, administrative and political elements that utilizes scientific and other technical expertise and knowledge as an input to that decision. I emphasise that the science does not make the decision, it is just one of the important guides as to what the decision should be. EIA was adopted to redress the balance away from purely economic concerns being heeded in decision making, and so it was designed to focus the proponent upon the environment as an issue for the proposed development or activity. Thus the environment becomes a concern of the proponent as part of the formal proposal.

Accordingly, scientists involved in EIA need to understand the roles of environmental impact statements (EISs) as political tools and documents of beliefs about potential impacts. Why are they written? As a tool in EIA, to be statements based in science, but above all as advocacy documents to justify the proposal. This advocacy role needs to be acknowledged because the cost of producing the EIS belongs to the proponent and so therefore should the thrust of the EIS. What ought they contain? The scientific understanding of the proposal and what impacts will ensue. This will incorporate modifications to the proposal to ameliorate any predicted impacts. How are they reviewed and evaluated? Informally by scientists as peers and more formally (but with less public transparency) by bureaucrats and administrators as part of arriving at the eventual decision. In some cases the courts or Commissions of Inquiry decide upon their adequacy. What role do EISs have in decision making? EISs give the scientific basis for the proponents' beliefs about the type and severity of impacts to occur from a project, but they are not the sole evidence by any means (Stein 1992). Much occurs before and after an EIS appears.

The role for scientific research in EIA is mandated by law (as a requirement of EISs) and the aims of science to describe, explain, predict and control natural phenomena are therefore relevant (Fairweather 1989). Before, during and after development there is a role for science in the assessment (i.e., prediction), monitoring and audit of environmental impacts; unfortunately this potential is rarely reached. The nature of science is to doubt, argue and question "facts" about, and our understanding of, any situation. This does not necessarily transfer very well into a court of law or other decision-making body (Lunney 1992; Stein 1992; Ayala and Black 1993; Peterson 1993).

PROBLEMS WITH THE RESEARCH USED IN EIA

There are difficulties with the use of scientific research in EIA as it is done now (Fairweather 1989). I discuss these under three broad headings but I plan to present elsewhere the detailed examples, including quotations, that underlie these generalizations.

Research Relevance

Some important issues are not addressed in some EISs because they are too hard (e.g., there was little on the impacts of sources of fill for Sydney Airport's third runway, see Fairweather and Lincoln Smith 1993); on the other hand some quite trivial questions (e.g., concerning outdated theories of ecological succession in coastal swamps, see Mitchell and Adam 1989 for a more current interpretation) may take up considerable effort and space in the final EIS. Scientists tend to find fault with such environmental documents, especially the static view put forward in EISs of what are essentially dynamic ecological processes. The descriptions of nature in them tend to be limited by the frames of time and space adopted for the studies done; yet nature is much more variable (Fairweather 1993). A simple species list is not dynamic. Nature consists of a rich cacophony of interactions that are largely unaddressed in EIA. Therefore most EISs do not give a functional view of the natural ecosystemic services we tend to take for granted like air and water quality, soil fertility, natural pest control, and exploitable resources. Therefore, as an ecologist, I want an EIS to tell me what is going on in that ecosystem, not merely what is there. A related point is that there is often an emphasis on the loss, and not recovery, of impacted habitats (Fairweather 1993).

There is a reluctance to admit our very real ignorance about some interactions in nature, owing to the fact that Australia is a vast land and we have few biologists and other environmental specialists to try to understand a wide array of habitats. This reluctance is hazardous because the context of assessments is often too narrow; where it is only an evaluation limited to the specific site where the proposal is located. Much of the information dealt with in an EIS is likewise site specific, which does not allow for much carry-over to the next similar case of the findings in an earlier set of surveys done for past developments. This limited portability limits the relevance of the EIS as a document of scientific interest. If the research were put into a wider context; then portability would be increased, e.g., with more extensive sampling regimes to provide some context for other assessments, e.g., the Jervis Bay fish studies used external control sites, some of which were in locations subsequently affected by the third runway (McNeill *et al.* 1992).

Allen and Hoekstra (1992, p. 265) point out that to document the full range of potential impacts EISs require ecological assessments be made at a number of conceptual levels (e.g., ecosystems, communities, landscapes) that are traditionally kept distinct via specializations that are difficult to overcome. This is especially so when particular "add-on" acts of parliament, such as in New South Wales for a Faunal Impact Statement (FIS, as outlined in the National Parks and Wildlife Act 1974 as amended by the Endangered Fauna (Interim Protection) Act 1991) to be prepared in addition to the EIS, serve to focus attention on the individuals, populations and habitats of wildlife, and then only for those terrestrial vertebrates that are listed as endangered. Thus the path to carrying out EIS studies is conceptually quite difficult and requires perhaps a broader training than nearly all ecologists get nowadays. Certainly few practising ecologists claim to work with more than one or two of the following levels: landscape; ecosystem; community; population; and behavioural ecology.

Research Quality

Coupled with this rather narrow view of the research question, some environmental work can be criticized for using inappropriate methodologies, or at least not the most recent ideas or techniques (Peterson 1993). The constraints of scale and scope discussed above (perhaps necessary because the study is tied to a date for a decision) also present real technical limitations to do with how much research can be done and how good it can be to answer ecological questions. This leads to a major difficulty with the final assessments made for any site: if you don't know what's there, how can you know whether or how to protect it?

The lack of referencing that is common to many EISs is not standard scientific practice. This again suggests that environmental studies tend to be more inwardly gazing than mainstream ecological research. Such a situation must exacerbate the risk of falling behind in the techniques and methodologies applied. In some cases the lines of reasoning can be quite puzzling, as if the consultant is bending over backwards to cast the proposal in the most favourable light; this contrasts with the more cautious and even sceptical tone adopted in scientific papers (which have already survived the normal scientific peer review).

Without routine publication within the mainstream of science, EIA-type science seems to be evolving into a parallel universe, trapped several decades behind in terms if techniques and ideas (Fairweather 1993). Indeed some EISs look as if they could have been written in the 1920s or so because they are merely descriptive. Some EISs are so appalling in scope, reasoning and presentation that from my viewpoint as an editor and teacher, rejection and failure would be all too common if EISs were submitted to me at the *Australian Journal of Ecology* or at the university, respectively.

Research Accessibility

EISs and most other environmental documents coming from both the private and public sectors epitomize the "grey" literature, lacking in any or all of: widespread publication; thorough peer review; and routine bibliographical listing. There may be little publicity about the production of an EIS, despite the requirement to notify both locally and in newspapers. They can be quite expensive documents to procure, are advertised for limited times and sometimes only a few copies are produced, such that not all interested parties are reached by, say, an FIS. As such EISs can get "lost in time". A example of this arose in a dispute (see Lewis and Clements 1993; Buckney and Morrison 1993) over a manuscript submitted to the *Australian Journal of Ecology* by some university ecologists. Peer review of the original manuscript was made difficult because the reviewers and editor did not have ready access (e.g., in the closest academic library) to an EIS which related to the results but was produced some 17 years before.

With the number of environmental studies going on in Australia recently (e.g., benthic studies offshore of Sydney, see Fairweather and Lincoln Smith 1993), there is a considerable duplication of effort occurring, combined with a lack of sharing of data and ideas (Stein 1992). Proponents and consultants sometimes seem wary of this to the point of being suspicious of the motives of anyone requesting information. Freedom of information legislation only seems to have increased this paranoia amongst bureaucrats involved in decision making who wish to resist public scrutiny.

From a purely scientific point of view, the worst problem with EISs is also the easiest fixed; the lack of peer review separates this sort of science from all others. I was sceptical of our reviewing system until I became an editor and could see how much it actually improves the average scientific manuscript. Peer review might prevent some of the more iniquitous problems with EISs, e.g., information lost from technical reports, being stripped of caveats and other scientific input between the biological survey report(s) and the final impact statement that leads to a gross simplification and truncation of the science presented.

Case Studies: the State of the EIS Art

To assess the quality of EIS documents as pieces of scientific literature, I have attempted a number of critical analyses of the characteristics of EISs and what they contain, and therefore their scientific and managerial value.

1. Fairweather and Lincoln Smith (1993) reviewed 42 EISs for marine or estuarine proposals to examine the requirements that the Director of the New South Wales Department of Planning had placed on the scope of the issues to be addressed (e.g., legal points, regulations, generic or specific issues to address and required consultations). We found that the scientific issues (e.g., as broad as "marine ecology") were identified by the Director as being required far less often than legal or administrative issues (e.g., under which part of the relevant Act is this being done or the need to consult with other government departments). We concluded that the guidelines are not at all a good guide as to the substantive scientific issues that should be dealt with in the assessments. This lack of scientific guidance may explain the uneven or poor science in some assessments.
2. I have assessed 131 EISs in terms of what sorts of biological research they contain (Table 1). Only 70 per cent of those

reviewed included any sort of ecological survey, less than a half provided species lists for the site and the collection of quantitative data occurred in less than a third. It is notable that the few data that were collected were generally not analysed in any formal way. Although we might not expect every EIS to contain the same amount or type of information, this sort of breakdown (Table 1) is notable for several reasons: (1) isn't the biology of a site always of interest for predicting environmental impacts?; (2) the taxonomic coverage is very uneven, seen not only by comparing the effort applied to plants and animals (terrestrial vertebrates generally), but hardly anything is considered of invertebrates and micro-organisms; (3) the research used is more qualitative than quantitative and therefore it may be more widely open to interpretation; and (4) there is a stark contrast with the norms of ecological research in general, where statistics are routinely used to aid interpretations by poking through the apparent chaos of nature to get at any signal of interest. This leads to a syndrome in EISs of using poor designs of studies yet making sweeping statements of no effects. I conclude that impact assessment is not typical of science.

Table 1. The use of biological and ecological science in a sample of EISs produced between 1972 and 1992 under various states' legislatures. Details of the EISs examined and a fuller analysis will appear in a later publication (Fairweather, in prep.).

Types of scientific data	Number	Per cent
Ecological surveys	92	70
floral	81	62
faunal	77	59
Species lists	57	44
Quantitative sampling of data	38	29
Statistical analysis included	10	7.6
Analysis done well*	3	2.3
Total EISs examined	131	100

*my assessment (as an editor, researcher and lecturer) of the data and analyses as presented in each EIS, using the common standards of experimental design and analysis (see stastical references in Fairweather 1991, 1993), but it was often hard to judge.

MONITORING AND AUDITING PREDICTIONS FROM EIA

Logically, it is appropriate to apply a hypothesis-testing framework in environmental work (Fairweather 1991), where the hypothesis under test is the predicted impact (or lack of it) coming to light during the EIA phase of a project. The EIA process and forthcoming approvals are thus the sources of the predictions. Monitoring and audit are rather separate procedures for environmental protection. Monitoring should occur throughout the construction and operational phases of a development or activity so that they can be used as a guide to modify operations. Audit usually occurs some time after a project has been operational and allows a "taking stock" of the success or otherwise of the environmental protection aspects of the project. Lessons can, and should, be learned from audit for later, analogous projects. Baseline monitoring does not usually relate to specific predictions coming from EIA and is probably only cost-effective in the sense of state-of-the-environment reporting or to assess the collective effects of many activities and developments (e.g., on a regional scale).

The connection between monitoring and audit is a logical one, in that without the results of a monitoring programme it would be impossible to audit the environmental performance and outcomes of a development or activity (Fairweather 1990a; Buckley 1991). For example, an audit might focus upon the *frequency* of exceeding some standard of emission, but this can only be determined from the results of regular, frequent and probably extensive monitoring of those emissions. To be truly scientific, the EIA predictions need to be tested by monitoring and audit.

Thus, the research in monitoring is not primarily motivated by seeking patterns in nature nor divulging relationships nor even generating environmental baselines; it must relate to predicted or suspected impacts. Monitoring must be much more focussed on the predicted impacts, and so should be more achievable (because the most powerful statistical and logical tools are appropriate and the objectives of monitoring are easily expressed in statistical terms, Fairweather 1991). The time is past for merely hopefully sifting a morass of data coming from monitoring (Fairweather and Cattell 1990).

This, in turn, means that we must focus on the intention of the monitoring, i.e., what is the research question under examination by the monitoring. There must be agreement between the question asked and the variable(s) studied, *viz.* which variable (of so many in the environment) is the one to measure to answer your question? What frequency and location of sampling? The most critical test will be possible when the hypothesis is stated as formally, quantitatively and precisely as possible. For example, it is a much more straightforward task to test whether an effluent exceeds a certain particle concentration when that concentration is specified along with the nature and size of particle and the measuring technique. In contrast, the statement that "no significant (or untoward or deleterious or substantial, etc.) increase in particulates will occur" is much harder to pin down because the research question is so ill-defined. Early agreement on the key questions of impacts allows for a streamlining of the monitoring programme, so that it becomes more efficient and effective within the budget allocated for monitoring (Fairweather 1991). So, always ask yourself: how precisely can I pin down these predictions? Precise questions lead to precise answers, thus focussing on important issues can only improve the science. Our science is better at quantitative decisions than merely judgmental ones.

An overt design component during planning is crucial to the success of a monitoring programme. At first, the research question is clearly defined because the types and styles of questions must determine the design of the study and therefore the collection of the data used to test predictions. This could be done with a "tender" or comment phase during which scoping of the study would involve all interested parties (including scientists, their societies and public participation). With poor or under-resourced research designs we run the risk of making only weak tests of our predictions (i.e., our tests have low power, Fairweather 1991). Environmental agencies should require estimates of detectable effect sizes (see Fairweather 1991) in proposed monitoring programmes if the consulting scientists do not provide them (e.g., the Great Barrier Reef Marine Park Authority now routinely asks for such power calculations).

Science is not objective, of course, but it does strive to be internally consistent (via the practices such as peer review). Therefore the use of external authorities to advise on monitoring is essential. Only by the involvement of persons at "arms length" can we ensure that internal prerogatives (i.e., not in the public interest) are not driving the monitoring agenda. Evaluation by academic institutions, for instance, can be used to "short-circuit" commissions of inquiry. Monitoring should be done by dedicated teams, although not necessarily those involved in the EIA phase. This is because monitoring is usually a longer-term activity than impact assessment, and can be large and expensive exercises rolling on for years. This effort requires keen insight and experienced minds, should involve innovations in outlook and techniques along the way, and be assessed like any good science (the last point should apply even more so where any research is "applied"). Peer review is the norm of all other science, so why not environmental monitoring? Thus, a review process should apply to the monitoring part of the exercise, whereby tenders from organizations interested in doing the monitoring are evaluated for their design and other aspects of scientific soundness by independent peers. Obviously this would be easier than at present if all determining authorities routinely required that approved monitoring schemes be lodged as part of the final approval process.

Whatever methodology used elsewhere in the world is no guarantee of absolute quality. We must always strive harder for accuracy, precision, repeatability, realism and generality *of our chosen environmental measurements* and methodology. Too often we measure whatever is in effluents rather than what is their effect, simply because the former is easier. This is a specific case of the general malaise of measuring what can be easily measured ("can do") rather than what we should estimate to answer the question ("need to"), or to paraphrase energy analyst John Holdren (Fairweather 1990b): we do not pay as much attention to what counts rather than what is countable!

There needs to be a regularized procedure for the use of monitoring results via a feedback into the project operation, regulatory safeguards and future practice. Monitoring is meaningless if it proceeds with no prospect of spurring warranted action. As the bottom line, results from monitoring and audit are the real "proof of the pudding" for environmental assessment procedures. Our understanding of the various ecosystems and our impacts upon them are ultimately put to the test in this forum. We can use this information to calibrate and verify our understanding of the system (Walters 1993). If we do not get it right, we should be able to learn for next time, and this can feed back into "pure" environmental science (Fairweather 1989; Walters 1993).

HOW CAN WE GENERALLY IMPROVE THE STATE OF THIS ART?

My four broad suggestions for strengthening environmental impact assessment procedures would involve changes to environmental management in New South Wales and elsewhere. They tend to revolve around an earlier, wider and better scientific involvement to aid the difficult task in front of public service managers and the public (Fairweather 1990b), including:

Greater Public Involvement

We should consider expanding the community basis of the EIA process by inviting public comment at an earlier stage, e.g., during the tendering phase. It is always possible to ask the public what they want rather than leave it up to the "experts". A public inquiry during the scoping phase (limited to genuine stakeholders and by the size of project) can decide on the questions to be addressed, the criteria for assessments and, more generally, what we are trying to do in that case of EIA. Certainly the chances of doing so would be better than the bureaucratic, "arms-length" process that we currently have. For example, we might increase the interaction points for the interested public (who are now knowledgable about environmental and planning issues). Presently direct public input is confined to two phases: public exhibition and comment, and any public inquiry that might follow a decision. I think there is much potential for public comment upon the guidelines and scoping of assessments, any draft evaluation (before release of the final EIS) and the assessment reports of the final version.

Many authorities do not seem to recognize that information consultation participation. To reverse the onus of burden of proof (Constable 1991) or adopt the precautionary principle to guide our decisions in novel ways is to put the power back with the people. We should beware the "tyranny of small decisions" winning over proper planning and "prognostic" studies (*sensu* Fairweather 1993).

Risk assessment *per se* may help here. The necessary steps in formal risk assessment include identifying the public hazard, estimating the level and/or extent of potential harm, evaluating the relative acceptability of this danger, and managing the hazard as appropriate (see Shrader-Frechette 1991). Scientists are also part of the public and so should be part of this process outside of their roles as consultants or technical assessors for government departments. At present scientists almost covertly provide ammunition for environmental pressure groups. Maybe we need some form of environmental legal aid to allow all parties to gain the services of technical experts? Perhaps challenges in the courts are needed to "refine" our environmental administration, e.g., environmental groups are beginning to charge maladministration of the relevant Acts via the courts by demonstrating that impacts were ignored or dismissed in some particular cases. This seems to me to be a valid use of scientific information about impacts in the public interest.

Regular Peer Review

We must involve scientific professionals to review proposals for EIA projects, as is done throughout science for grants and publications (i.e., to apply the same standards to all environmental research, whether pure, applied or commissioned). Hopefully we could receive more consistent evaluations by involving other, independent scientists in an overview role. More clear support from the scientific establishment for "whistle blowers" and others who expose corrupt behaviour involved in environmental decision making would also be welcome.

Institutional Reform

We need more public debate about the sorts of scientific questions that should be examined in environmental research. We need to examine questions like: who should pay for having an EIS written? Can we build more independence into the system? Should there be tax deductibility for environmental research that is in the public interest to defray the tendency of the proponent to skimp on research to defray costs? This should build public support for projects that attempt to examine environmental issues properly. Graduate students could perhaps focus their theses on reviewing past performance in particular sectors of the environmental industry. Then there should be some follow through to financially support future quality proposals in that area. Institutional evaluation by government departments needs to be a more transparent process. More institutional (e.g., from granting agencies) acceptance of interdisciplinary approaches that try to examine environmental questions from a variety of perspectives would be a gain. Likewise more regional and national research on the environment would be welcome, plus freer exchange of information amongst authorities, to provide a more clear context for deciding on particular evaluations of impact. Regarding evaluations of EISs, maybe we need to separate the specialist sub-consultant from the consultant writing the EIS, plus append all the sub-consultant reports to the final EIS?

Legitimising impact assessment as an academic study in its own right

The only way to get scientists off their collective backsides and onside is to subject EIA research to all the checks that good science has to go through. Scientists should also realize the genuine research opportunities inherent in a better standard of impact assessment, e.g., the chance to do large-scale research (Walters 1993) or to integrate research across traditional disciplines or to concentrate on those currently ignored. Being innovative may involve responding to future threats by what Fairweather (1993) termed "prognostic" research as well as the chance to utilize new techniques, evolving concepts or previously overlooked steps. "What are the limits to acceptable change to the environment?" is an example of the crucial research questions that are challenging both scientifically and socially, and currently confront our decision making about environmental issues.

CONCLUSION

Many practising scientists seem to shy away from involvement in impact assessments or similar environmental consulting work because they perceive such research as inadequate by normal standards. This is often due to them feeling hampered by the constraints placed on environmental consultants in terms of time and intellectual freedom. Yet such attitudes result in the paradox that the standard of assessments cannot improve until the wider scientific community takes environmental practice under its wing, as a legitimate discipline, much as conservation has gained respectability under the rubric of "conservation biology".

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